

Short Communication

Is high sodium intake associated with hearing impairment? The association between spot urine sodium concentration and hearing threshold in Korean adolescents

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Background and Objectives: High sodium intake is a well-known risk factor for diseases such as cardiovascular and renal disease. There may also be links between sodium intake and inner ear symptoms. However, the available data are limited, and clinicians remain suspicious about sodium intake and hearing threshold. We analyzed the relationship between spot urine sodium concentration and sensorineural hearing loss in Korean adolescents.

Methods and Study Design: A total of 534 subjects, aged 12–19 years old, were enrolled in this study. Sex, age, hearing threshold, and overnight spot urine sodium concentration were measured. Multivariate logistic regression analysis was performed to estimate the independent effect of sodium intake on hearing level. **Results:** Higher urine sodium concentrations were observed in subjects with hearing impairment in 2000, 3000 and 4000 Hz. After adjusting for sex, age and BMI, we found an association between urine sodium concentration and sensorineural hearing loss in 500, 2000, 3000 and 4000 Hz. **Conclusion:** Our results suggest that high sodium intake might be associated with hearing impairment.

Key Words: Sodium intake; Urinary sodium; Hearing threshold; Adolescent; Hearing loss

INTRODUCTION

High salt diets are associated with imbalances of electrolytes and hormones which cause health problems.¹ Many diseases such as stroke, renal disease and hypertension are related to high salt intake.^{2,3} Therefore, reducing dietary salt intake is an important public health issue as well as an issue of personal choice.

Restriction of salt intake is a clinical treatment option for otologic diseases such as sudden sensorineural hearing loss and Meniere's disease. Otologic symptoms are abruptly aggravated after high salt intake in patients with Meniere's disease.⁴ However, data regarding the effects of high sodium intake on hearing in normal subjects are lacking. Therefore, we investigated the relationship between high sodium intake and hearing. However, obtaining exact measures of daily sodium intake is difficult. Dietary recall and 24-hour urine collection analysis are normally used, but 24-hour dietary recall is usually not accurate and 24-hour urine collection is inconvenient.⁵ To overcome these challenges, overnight spot urine sodium concentration was adopted to represent daily sodium intake in the present study.⁵⁻⁷ We investigated the relationship between overnight spot urine sodium concentrations and sensorineural hearing loss in Korean adolescents using data from the Korean National Health and Nutrition Examination Survey (KNHANES) 2010.

MATERIALS AND METHODS

KNHANES 2010 was a cross-sectional survey conducted by the Korean Ministry of Health and Welfare. Physical ear examinations were conducted by otolaryngologists in all subjects to detect ear problems. Each participant's hearing threshold was measured in a soundproof booth with an automatic audiometer. We defined a threshold for hearing impairment of 30 dB or greater and considered a subject to be hearing impaired if at least one ear exhibited hearing loss. Hearing ability was analyzed at the following frequencies: 500, 1000, 2000, 3000, 4000 and 6000 Hz. Random spot urine samples were obtained in the early morning if possible. Urine sodium concentration was measured using a Urisys 2400 (Roche Ltd, Germany).

We limited our analysis to subjects aged 12-19 years old and excluded data from participants with renal or ear disease. The demographic data were given as quartiles

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divided by spot urine sodium concentration. The Mann-Whitney test was used to measure differences in sodium concentration, and multivariate logistic regression analysis was performed to estimate the independent effect of sodium intake on hearing level. SPSS 17.0 (SPSS Inc., Chicago, IL, USA) was used for all analyses. A p -value <0.05 (two-tailed) was considered statistically significant. This study was approved by the institutional review board of the Jeju National University Hospital, in accordance with the Declaration of Helsinki.

RESULTS

Of the 534 subjects, 305 were male and 229 were female. Mean 24-hour sodium excretion was higher in males (142.9 ± 68.9 mEq/L) than females (132.1 ± 62.4 mEq/L), but this difference is not statistically significant ($p=0.06$). Urine sodium concentration ranged from 13 to 437 mEq/L and stratified by quartile. The quartile cutoff points were as followed: 1st quartile, <88 mEq/L; 2nd quartile, $88 \leq$ and <129 mEq/L; 3rd quartile, $129 \leq$ and <180 mEq/L; 4th quartile, ≥ 180 mEq/L. Systolic BP and BMI increased across groups according to increases in sodium concentration. However, the male: female ratio, mean age, mean systolic/diastolic blood pressure (BP), and mean body mass index (BMI) did not significantly differ between quartile groups (Table 1). Mann-Whitney test indicated that urine sodium concentration was higher in the hearing-impaired group than the normal group for all frequencies, but the differences were only statistically significant at 2000, 3000 and 4000 Hz (Table 2). We performed multivariate logistic regression in which we adjusted for sex, age and BMI, and found that high sodium concentration was positively correlated with sensorineural hearing loss (500Hz: OR 1.008, 95% CI 1.001-1.015; 2000Hz: OR 1.008, 95% CI 1.002-1.014; 3000Hz: OR

1.009, 95% CI 1.004-1.015; 4000Hz: OR 1.009, 95% CI 1.004-1.015).

DISCUSSION

We detected an association between high urine sodium concentration and prevalence of sensorineural hearing loss among Korean adolescents. This is the first study to explore the relationship between urine sodium concentration and hearing loss, and our results suggest that high sodium intake plays a role in sensorineural hearing impairment.

We were unable to determine the exact mechanism through which high sodium affects hearing, and the existing data are insufficient to illuminate this relationship. However, hypertension is related to hearing impairment in adults.⁸ In the present study, BP was higher in the group with hearing loss compared to the normal group, but not significantly. We therefore, suspect that a relationship between high BP and hearing ability exists in adolescents as well.

Cate et al. reported that a low sodium, high potassium diet may lead to significant increases in Na⁺, and K(+)-ATPase levels in cochlear lateral wall tissue in rats. They suggested that this may be the mechanism by which salt restriction and potassium loading have beneficial effects for patients with Meniere's disease.⁹ Rarey et al showed that ionic alterations in cellular potentials may be involved in hearing changes in hypertensive rats.¹⁰ This study has some limitations. First, exact measurements of daily sodium intake are difficult, and one time measurements may not adequately represent daily sodium intake. More precise methods such as serial or repeat 24-hour urine collection are required for more accurate estimates of daily sodium intake. Second, we did not consider other variables that may affect the hearing ability, such as noise

Table 1. Demographic data of study population

		n	Overnight spot urine sodium concentration				
			1st quartile	2nd quartile	3rd quartile	4th quartile	
Sex	Male (n)	305	69	77	78	81	
	Female (n)	229	62	57	58	52	
Age (years)			15.3	14.9	15.1	14.7	
BP	Systolic (mmHg)		103.3	104.6	105.5	105.5	
	Diastolic (mmHg)		64.7	65.7	64.9	65.3	
BMI			20.7	20.9	21.1	21.8	
Frequency	500 Hz	≤ 25 dB	523	131	132	131	130
		≥ 30 dB	11	0	5	3	3
	1000 Hz	≤ 25 dB	518	130	128	132	128
		≥ 30 dB	16	1	6	4	5
	2000 Hz	≤ 25 dB	519	131	128	132	128
		≥ 30 dB	15	0	6	4	5
	3000 Hz	≤ 25 dB	517	131	128	131	127
		≥ 30 dB	17	0	6	5	6
	4000 Hz	≤ 25 dB	512	131	126	129	126
		≥ 30 dB	22	0	8	7	7
	6000 Hz	≤ 25 dB	470	117	119	115	119
		≥ 30 dB	64	14	15	21	14

BP: blood pressure; BMI: body mass index.

Table 2. Difference of median overnight spot urine sodium concentration between the hearing impaired group than the normal group (A) and the association between overnight spot urine sodium concentration and hearing threshold according to frequency (B)

Hearing threshold		Overnight spot urine sodium concentration				
		Mann-Whitney test (A)			Logistic regression [†] (B)	
		Mean rank	Z	p-value	OR (95% CI)	p-value
Hz 500	≥30 dB	329.1	-1.34	0.18	1.008 (1.001-1.015)	0.03
	≤25 dB	266.2			Reference	
Hz 1000	≥30 dB	324.6	-1.50	0.13	1.005 (0.998-1.012)	0.15
	≤25 dB	265.7			Reference	
Hz 2000	≥30 dB	349.5	-2.09	0.04*	1.008 (1.002-1.014)	0.01*
	≤25 dB	265.1			Reference	
Hz 3000	≥30 dB	357.9	-2.44	0.02*	1.009 (1.004-1.015)	<0.01**
	≤25 dB	264.6			Reference	
Hz 4000	≥30 dB	351.1	-2.59	<0.01**	1.009 (1.004-1.015)	<0.01**
	≤25 dB	263.9			Reference	
Hz 6000	≥30 dB	276.6	-0.50	0.62	1.002 (0.998-1.006)	0.33
	≤25 dB	266.3			Reference	

OR: odd ration; CI: confidence interval.

[†]Adjusted by sex, age and BMI.

*indicate significance at $p < 0.05$, ** $p < 0.01$.

exposure or medications. We limited our subject pool to adolescents who were affected less by other factors than those that affect adults. Finally, we did not consider the renal function of individual subjects, even though we excluded subjects with renal disease. Therefore, there was possibility that the individual difference of renal function might affect the urine sodium concentration.

In conclusion, high urine sodium concentration is associated with hearing impairment in Korean adolescents, especially at frequencies of 2000, 3000 and 4000 Hz. This suggests that high sodium intake may cause sensorineural hearing loss. Further studies are needed to draw more concrete conclusions about this relationship.

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AUTHOR DISCLOSURES

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